THE POSITION OF THE RESPIRATORY AND CARDIO-INHIBITORY FIBRES IN THE ROOTLETS OF THE IXth, Xth AND XIth CRANIAL NERVES.

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THE experiments which are described in this paper have been undertaken with the object of determining the functions of the rootlets of the ninth, tenth and eleventh cranial nerves as they leave the medulla. Although anatomically arranged in three groups, this grouping, as is well known, does not correspond to the three large nerve trunks as they issue from the base of the skull.

The present paper deals with three sets of fibres only, viz., the respiratory (Hering-Breuer) fibres, the efferent cardio-inhibitory fibres, and the afferent fibres of the vagus excitation of which causes reflex cardiac inhibition.

Cats and dogs were chosen for the experiments, and they were throughout anæsthetised with the A.C.E. mixture. The animal having been anæsthetised, the two carotids were exposed, one was ligatured, and a cannula was tied in the other so that the blood-pressure could be subsequently recorded. A cannula was next tied in the trachea. Loops of thread were passed round the two vagi in the neck, the vagi being separated from the cervical sympathetics. The ligature of both the carotids prevented a great deal of the bleeding in the later stage of the operation while the circulation in the brain and medulla was little affected. The medulla was always found to be quite sensitive and to give good reflexes.

The animal was now turned over, the left temporal muscle was reflected and the muscles of the back of the neck removed on either side so as to thoroughly lay bare the occipital bone, occipito-atloid ligament and atlas. In reflecting these muscles care must be taken to

ligature a large artery and vein issuing with the first cervical nerve. The occipito-atloid ligament was cut in the middle line and the dura mater separated from the lower margin of the supra-occipital bone. The whole of the supra-occipital, and a small part of the posterior border of the left temporal bone was then rapidly removed. Considerable bleeding takes place from the sinuses as they are cut across. This is at once checked by having the head of the animal raised well up above the trunk, and the sinuses are then plugged with wax. The skull was cut freely away laterally; the bleeding at each cut being stopped as before. Great care is taken throughout this stage that the dura mater is not injured. Sufficient bone having been removed to allow of free exposure of the rootlets, the dura mater was incised in the middle line and thrown down towards the left side. Upon now gently displacing the cerebellum the rootlets of the three nerves can be brought into view. The rootlets lie at the bottom of a deep conical space in which the blood, from the torn small vessels, collects and effectually prevents a view of any single rootlet sufficiently distinctly to allow of its section. To avoid this difficulty small pledgets of cotton wool with clean cut edges were prepared of such a size as to fit the space: these were inserted and pushed gently against the cerebellum and medulla. The pressure necessary to push aside the cerebellum at the same time stops the bleeding which occurs from this surface, and, in this way, the rootlets can be brought into clear view and divided as necessary.

At first it was attempted to determine the functions of the rootlets by exciting them directly with induction shocks, but this proved most unsatisfactory as, in the first place, the working space is so contracted, and secondly, the rootlets lie so close together, that it is impossible to prevent escape of current to other rootlets than the one excited. Excitation reflexly was, therefore, employed in all the later experiments. The plan of the experiment was to obtain a reflex through the rootlets, and then to cut a single rootlet and note if the reflex had been in any way affected.

The rootlets, as is known, are arranged in three groups[1]. In the cat the uppermost consists firstly of one large rootlet, and this is followed by one, or sometimes two, rather smaller rootlets. The second group is made up of a series of about eight to ten small rootlets which follow each other closely forming a band-like arrangement: these lie on a plane a little posterior to the upper group. The third group

[1] Cp. Kreidl, *op. cit. infra* and the papers there quoted.

generally consists of three distinct rootlets situated in the angle between the spinal portion of the spinal accessory nerve and the medulla. These will be referred to in this paper as the first, second, and third groups respectively.

In the dog the arrangement is much simpler. All the fibres leave the medulla in three large rootlets, which correspond to the groups of rootlets found in the cat. The three big rootlets are also well separated from one another.

Section I. *The respiratory fibres.*

In order to determine the rootlets in which these fibres enter the medulla, experiments were carried out in the following manner. The rootlets having been exposed on the left side of the medulla, the right vagus was then divided in the neck.

The left uncut vagus was now excited by weak induction shocks to show that it produced arrest of respiration. After recovery from this excitation the rate of respiration was counted. The uppermost bundle of the first group was now divided and any effect on the rate of respiration recorded. Similarly the rootlets were divided one by one from above downwards, watching for the slowing of respiration which follows division of both vagi in the neck. After each rootlet was divided the left vagus was excited to see if any effect upon respiration resulted. There were therefore two signs indicating that the respiratory fibres had been divided, viz.: (i) the slowing of the respiration and (ii) absence of effect on respiration when the left vagus was excited in the neck. By this experiment the lowest limit at which these fibres enter the bulb was determined.

By an exactly similar procedure, in other experiments, but starting with the lower rootlets and passing upwards, the upper limit by which the fibres enter was determined. Finally the experiment was made of picking out those rootlets only which lay between the limits determined by the earlier experiments.

In this way it was proved that the afferent respiratory fibres enter the bulb in the lower rootlets of the upper group. If there are two rootlets here, both contain respiratory fibres. If there is but one rootlet, all these fibres lie in that rootlet. Respiratory fibres were never found in the upper rootlet. Division of the rootlets of the second and third groups have no effect whatsoever upon respiration.

The arrangement in the dog is exactly similar. All the respiratory fibres enter in the upper rootlet.

SECTION II. *The efferent cardio-inhibitory fibres.*

The general plan of the experiments for tracing these fibres in the rootlets was as follows. When the rootlets had been exposed upon the left side the animal was placed on its back and the cannula in the left carotid connected to a mercury manometer. The right vagus was then divided in the neck and its central end excited electrically. The blood-pressure tracing gave the record of the cardiac inhibition. The animal was now turned over and the uppermost rootlet divided. The central end of the right vagus was again excited. The rootlets were now divided seriatim from above downwards and reflex cardiac inhibition watched for after each division. In this manner the lowest limit at which these fibres leave the bulb was determined. In the next animal the uppermost limit was determined, and, finally, by picking out the particular rootlets, the general result confirmed.

In this way it was shown that the efferent cardio-inhibitory fibres of the vagus leave the bulb in the two lowest rootlets of the third group. They are never contained in the upper rootlet or rootlets of this group, and, if there are only two rootlets present, the fibres are all contained in the lower one. In the dog the arrangement is the same; all these fibres run in the lowest rootlet.

SECTION III. *The afferent fibres excitation of which causes reflex cardiac inhibition.*

The course of this set of fibres was determined by an analogous set of experiments. The left vagus being cut in the neck, its central end was excited before and after division of the various rootlets. The absence of effect on the blood-pressure record gave the limits of the rootlets which carry these fibres into the bulb. It was thus proved that these fibres entered by the lower two rootlets of the first group. In fact, the entrance of these fibres is exactly the same as that of the respiratory fibres. This result, therefore, falls well into line with the results obtained by Brodie and Russell[1] on reflex cardiac inhibition. They

[1] See this number of the *Journal, infra.*

show that the branches of the vagus excitation of which results in cardiac inhibition are the pulmonary branches. Stimulation of the central end of the divided cardiac branches commonly produces no effect on the heart rate, sometimes it is slowed, but even then the inhibition is never so pronounced as that following stimulation of the pulmonary nerves. Similarly excitation of the vagi below the point at which the pulmonary nerves are given off frequently causes no inhibition and when the latter is produced it is never very considerable.

Observations on the function of the rootlets have been made by several observers. Grossmann[1] carried out his experiments upon rabbits, in which animal the arrangement of the rootlets is practically the same as in the cat. The occipito-altoid ligament was exposed and opened. No bone was removed. The rootlets were excited electrically and the effect upon the heart determined by recording the blood-pressure. Inhibition was only obtained when the lowest rootlets of the middle group and the highest of the lower group were excited. These results differ from those I have obtained upon the cat. I have not as yet attempted to confirm these results by the reflex method upon the rabbit. In the cat it is quite impossible to see the rootlets unless the bone be removed. Stimulation of the rootlets electrically is I think very untrustworthy for this purpose. While employing it I never obtained the precise and definite results obtained by the experiments above described.

Kreidl[2] also worked upon rabbits. Among other results he observed, he describes slowing of respiration as following the tearing through of all the rootlets of the upper group. His results therefore agree with mine, but he was not able to discriminate between the different rootlets of that group.

Beer and Kreidl[3] have employed a method which is practically the same as mine. Among other fibres they worked out the course of the respiratory and describe them as entering in the lower rootlets of the upper bundle. My results upon cats and dogs, therefore, agree very well with theirs upon the rabbit.

In a later paper Kreidl[4] gives the results of some experiments of the same kind upon monkeys (*Macacus Rhesus*). The rootlets were exposed and excited electrically. He found that the inhibitory fibres

[1] Grossmann. *Pflüger's Archiv*, LIX. p. 1. 1895.
[2] Kreidl. *Pflüger's Archiv*, LIX. p. 9. 1895.
[3] Beer and Kreidl. *Pflüger's Archiv*, LXII. p. 156. 1895.
[4] Kreidl. *Sitz. d. k. Akad. Wien*, CVI. p. 197. 1897.

for the heart left the bulb by the upper two rootlets of the middle bundle. The respiratory fibres enter by the lower rootlets of the upper group. As far as the respiratory fibres are concerned, my results upon the cat are in agreement with his upon the monkey. As regards the cardiac fibres our results differ materially. In my opinion the method adopted by Kreidl for determining the course of these fibres is not so satisfactory as the reflex method I have adopted. I have found that these fibres enter in quite the same position in both cat and dog, and in a successful experiment the answer given by the reflex method is very decisive.

I wish here to express my thanks to my friend Dr T. G. Brodie for his very valuable hints and great help in these experiments.